

Functional Foods Baseline and Requirements Analysis

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OBJECTIVES

Current spaceflight foods were evaluated to determine if their nutrient profile supports positioning as a functional food and if the stability of the bioactive compound within the food matrix over an extended shelf-life correlated with the expected storage duration during the mission. Specifically, the research aims were:

Aim A. To determine the amount of each nutrient in representative spaceflight foods immediately after processing and at predetermined storage time to establish the current nutritional state.

Aim B. To identify the requirements to develop foods that stabilize these nutrients such that required concentrations are maintained in the space food system throughout long duration missions (up to five years).

Aim C. To coordinate collaborations with health and performance groups that may require functional foods as a countermeasure.

KEY CONCEPTS

Functional foods, according to the American Dietetic Association, include whole foods and fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis, at effective levels.

American Dietetic Association (ADA). (2009). Position of the American Dietetic Association: Functional Foods. *Journal of the American Dietetic Association*, 109(4), 735-46.

The unavailability of fresh foods, fruits, and vegetables in the spaceflight food system makes it critical to understand the stability and capability to deliver **bioactive compounds** (carotenoids, flavonoids, phenolic acids and tannins) in a shelf stable food system over time.

Irina and Mohamed (2012) showed that thermal processing degrades most flavonoids and that freeze-drying was less aggressive than hot air drying but still resulted in flavonoid losses.

Irina, I., & Mohamed, G. (2012). Biological activities and effects of food processing on flavonoids as phenolic antioxidants. In: *Advances in applied biotechnology*: M. Petre (ed.), In Tech, Rijeka, Croatia. Chapter 5: Page 101-124.

METHODS

FOOD SYSTEM ANALYSES

A prospective list of spaceflight foods, thermo-stabilized and freeze-dried, was generated. The foods were pulled just after production, taken from inventory if the items were less than 3 months old, or specially produced in a smaller batch and freeze-dried to spaceflight specifications in the Space Food Systems Lab. The tested food items are listed in Table 1.

Food samples were sent to the Food Composition Laboratory of the Linus Pauling Institute at Oregon State University (Corvallis, OR) for bioactive compound analysis. The following tests were conducted:

- Vitamin K (HPLC)
- Vitamin E (HPLC)
- Vitamin C (HPLC)
- Carotenoids (HPLC)
- Sterols (HPLC)
- Phenolic, anthocyanins and antioxidants (Spectrophotometric, HPLC)
- Mineral analysis (ICP)

SHELF LIFE STUDIES

Duplicate of samples of the food were placed in 4°C, 21°C, and 35°C environmental chambers within the Space Food Laboratory for storage. After 3 months of storage samples were pulled from the 35°C chamber for repeat analysis. After 6 months of storage, samples were pulled from all three chambers and submitted for repeat analysis.

The stability assessment of the bioactive compounds will proceed over the course of two years. At the one-year storage time point, the food will be pulled from the 4°C, 21°C and 35°C chamber and undergo repeat analysis. Food stored at 4°C and 21°C will be analyzed again at the two-year time point.

Table 1. Selected spaceflight foods for bioactive compound stability study

	Flavonoids	Phenolics	Carotenoids	Omega-3 Fatty Acids	Sterols
Strawberries	X	X			
Cherry Blueberry Cobbler	X	X			
Granola w/ Blueberries	X	X		X	X
Wild Rice Salad		X		X	X
Brown Rice				X	X
Macadamia Nuts			X	X	X
Creamed Spinach		X	X		
Vegetarian Chili		X	X		
Cheese Tortellini w/ Tomato Sauce			X		
Salmon in Pouch				X	
Oatmega Dark Mint Chocolate Bar		X		X	X
Sweet and Savory Kale	X	X	X	X	

¹ International Space Station (ISS) provisioning bonus food selection but not part of the standard menu
² Not current ISS provisioning item but prototype consistent with spaceflight food parameters

RESULTS

Antioxidant Capability

The twelve foods of the study varied significantly in their FRAP antioxidant measurements at the initial time point with Strawberries having twice the antioxidant value of the next highest food. The comparison benchmark, cultivated strawberries FRAP value, is taken from Carlsen and others (2010).

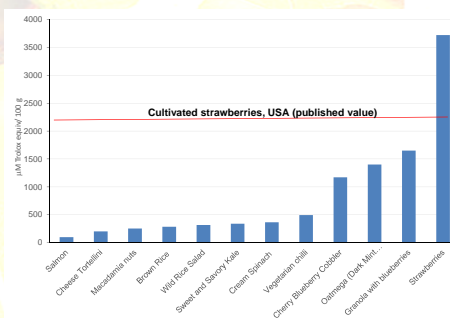


Figure 1. FRAP values for spaceflight foods

The phenolic content of the foods, an indirect measure of antioxidant capability, was assessed for eight of the foods with the highest expected antioxidant capability. Strawberries and the Dark Mint Chocolate Oatmega Bar had a significant concentration of phenolics, especially when compared to the average phenolic consumption by Americans on a daily basis (Figure 2). Initial shelf-life analysis indicates phenolics may be stable in several foods.

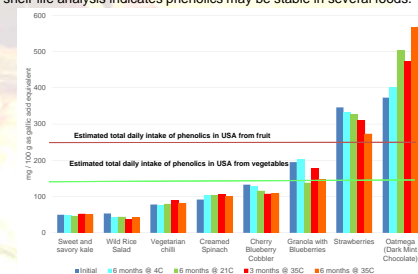


Figure 2. Total Phenolics values for spaceflight foods after processing and during shelf-life (3 and 6 months)

Flavonoids

The initial results showed that the flavonoid quantities are contributed as follows: **Strawberries > Granola with Blueberries >> Cherry Blueberry Cobbler > Sweet and Savory Kale**

Carotenoids

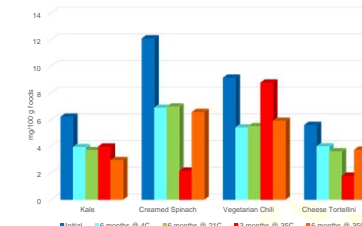


Figure 3. Total Carotenoids content for spaceflight foods after processing and during shelf-life (3 and 6 months)

Sterols

The sterols content of spaceflight food do not approach the required levels of cardiovascular benefit but initial concentrations are within the range of published values of sterol content in food (Almond 138.4 mg – Spinach 10.2 mg/100 g)

Table 2. Sterol content on spaceflight food during storage at different temperature

Spaceflight foods	Initial	3 months @ 35°C	6 months @ 4°C	6 months @ 21°C	6 months @ 35°C
Brown rice	3.79	4.96	4.84	5.18	5.29
Wild rice Salad	31	28.94	28.65	28.8	28.27
Oatmega Dark Mint Chocolate Bar	18.67	14.64	21.12	21.69	19.42
Macadamia Nuts	45.52	61.76	29.02	34.24	31.69

Fatty acids

Salmon in the pouch had the greatest concentration of omega-3 in the spaceflight foods, followed by the Oatmega bar. High concentrations of ALA omega-3 were found in some spaceflight foods, but conversion of ALA to EPA and DHA is very low. There was degradation of EPA and DHA during storage as shown in Figures 4 and 5.

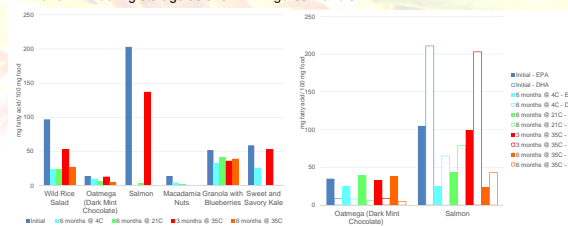


Figure 4. ALA (α-Linolenic fatty acid) in spaceflight foods after processing and during shelf-life

Figure 5. EPA (Eicosapentaenoic) and DHA (Docosahexaenoic) fatty acids in spaceflight foods after processing and during shelf-life

CONCLUSIONS

The ability to provision high-phenolics, high-carotenoids, or high-omega-3 foods within the spaceflight food system was demonstrated by the identification of the target foods and their initial chemical analysis during the first months of storage. Samples continue under controlled storage and nutrient content will be assessed after one and two years of shelf-life

- Fish products on the space menu are very limited, therefore omega-3 concentrations are limited.
- The use of foods for health benefit in space could be a challenge with the current menu.
- The identification of foods with high bioactive compound concentrations highlighted the fact that the ISS provisioning menu likely does not have a variety of foods with these compounds.

References

- Carlsen, M. H., Halvorsen, B. L., Holte, K., Bohn, S. K., Dragland, S., Sampson, L., & Blomhoff, R. (2010). The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. *Nutrition Journal*, 9(3), 1-11.